Solid Earth Discuss.,
https://doi.org/10.5194/se-2018-109-RC2, 2018

Solid Earth
Discussions

Interactive comment on “Power Spectra of Random Heterogeneities of the Solid Earth” *by* Haruo Sato

Cormier (Referee)

vernon.cormier@uconn.edu

Received and published: 26 November 2018

This is a timely and comprehensive review of the results for 3-D heterogeneity in the crust and mantle obtained from analysis of well-logs, body wave coda modeling, phase fluctuations of observed arrays, velocity tomography, numerical modeling, and radiative transport modeling. Key work on the validity of radiative transport modeling with the Born approximation is cited, calling attention to the use of phase screen approximations in the ma» 1 regime. Figure 8, which summarizes the heterogeneity power spectrum over a broad range of wavenumbers will be a valuable reference for future studies to use for comparison and refinement.

My comments for consideration are related to the validity of common assumptions of the heterogeneity power spectrum as a function of depth, the interpretation of the spectrum in terms of rheology, temperature, phase, and chemistry, and spectral complexity that may be hidden in log-log plots. These are:

(1) Validity of dlnVp/Vs = 1 assumed in the majority of coda studies. Although not cited in the review, the majority of coda studies employ it to simplify the scattering coefficients. Observationally in the crust and lithosphere it has been measured to be up to 1.5 (Koper).and in the deeper mantle, it has been observed to be > 2 (Romanowicz and others). Thermal effects and viscoelastic attenuation effect have been invoked to explain the observations.

(2) The validity of dlinrho/dlnVs = 0.8. Although the starting point for this assumption has been Birch’s law. Even the earliest literature suggested it breaks down with depth. In the deeper mantle, it would lead to very strong buoyancy effects and geodynamic modelers typically assume 0.1 to 0.2 (e.g., Forte et al.)

(3) Validity of (1) and (2) are sufficiently validated in the crust and lithosphere, but it would be important to note the depth of the validation from common assumptions or measurements of lithosphere thickness. 100 to 200 km?

(4) Incorporation of tomography determined heterogeneity. Even accounting for resolution limitations, there frequently has been a discrepancy in the intensity of the true heterogeneity power, measured by velocity fluctuation, epsilon. This is due to the effect of damping required in the inversion. When modelers try to match some observed waveform effects (multi-pathing) starting from tomographic models, they have shown that a factor of 2 or more must be applied to the tomographic inferred velocity fluctuations, e.g., Helmberger, Romanowicz, and co-workers. This scale factor may not be important at the x-y log scales of Figure 8, but still needs to be considered.

(5) All attenuation in the mantle due to scattering. Riccard’s suggestion is extreme, but is still important to highlight. It can probably easily be shown to be extreme if one considers the dispersive effect of intrinsic attenuation. The apparent dispersion

of pure scattering attenuation on a body wave pulse will be too small to account for the difference between body wave Earth models versus free oscillation derived free oscillation models, first noted by Dziewonski in the early 1970's. The contribution of scattering attenuation to total attenuation of teleseismic body waves is still an important problem to resolve. The minimum we can say at this point, however, is that the estimate of intrinsic attenuation derived from teleseismic body waves is probably always an over-estimate unless we are able to determine the scattering contribution.

(6) Kolmogorov spectrum. Although viscosity is large, there still may be some validity to consider the shapes and domains of this spectrum for thermally driven convection, similar to its original application to atmospheres. Most of the small-scale heterogeneity in the lithosphere is at scales (a <+ 10km) is most certainly chemical not thermal based on the estimated thermal diffusivities of known mantle materials. This small-scale material is not directly related to a Kolmogorov spectrum, but it is quite possible that larger scales (500 km and greater) are.

(7) Smoothness and complexity of heterogeneity spectrum. The mechanisms creating Earth heterogeneity argue for some complexity that may be hidden at a log-log scale. It is possible that over a broad scale, the heterogeneity spectra is multi-modal in character, with each mode driven by a fundamentally different mechanism. At large scale (several hundred kilometers and greater) there may be a thermally driven mode; at small scale may there is more of a pure chemical signature. For example, at the larger scale Stixrude and Bertolini-Lithgow have predicted peaks in the temperature derivative of upper mantle velocities due to chemical and phase stability at different depths, We (Cormier, Commun. Comp. Phys., accepted) have found a complex signature of lager scale upper heterogeneity that agrees very well with Stixrude and Bertolini-Lithgow. This spectrum consists of intense peaks in epsilon as a function of depth, separated by regions of low epsilon. My hunch is that mantle heterogeneity can be best explained by a superposition of this thermal/chemical large-scale heterogeneity (complex in depth) on top of a small-scale, convectively entrained, chemical heterogeneity.

(8) In the crust, there can also be rheogically driven divisions in a depth dependent small-scale heterogeneity, influenced by brittle-ductile transitions. Some evidence of this has been suggested by Rachman and Chung (BSSA, 2016), Badi et al. (GRL,2009) Bianco et al., (GJI, 2005).

Vernon F. Cormier, University of Connecticut

Interactive comment on Solid Earth Discuss., https://doi.org/10.5194/se-2018-109, 2018.